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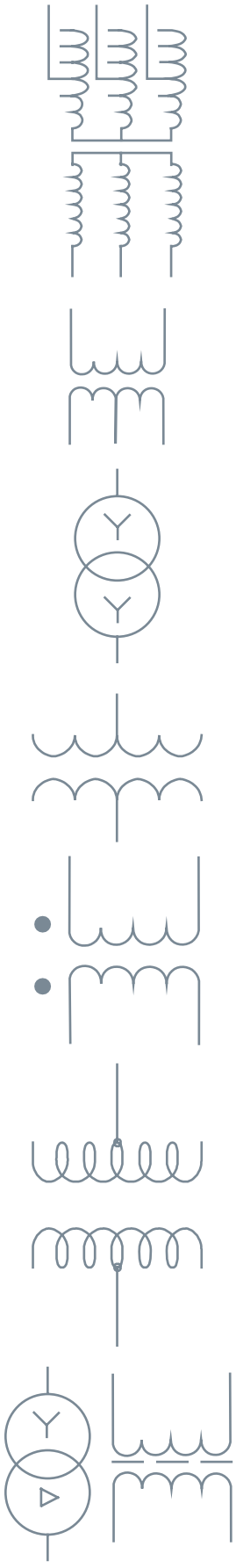

End User Benefits

of Winding Hot-Spot Temperature Measurement

As direct, real-time measurement of transformer winding temperature using fiber optics becomes more popular, the benefits to electrical utilities are becoming clearer. Unlike conventional methods that measure top or bottom oil temperature, fiber optic monitoring enables true "hotspot" measurement by sensing temperature directly at the windings. In addition to other benefits like thermal model calibration/recalibration, this direct, dynamic measurement allows utilities to:

- Verify transformer design integrity and manufacturing quality
- Safely maximize normal loading without damaging insulation or reducing transformer life
- Provides true dynamic loading capability

Verification of Transformer Design Integrity and Manufacturing Quality

The hottest spot temperature rise at a rated load is a necessary parameter for determining the loading capability of all transformers. IEEE Std. C7.12.00 specifies that the hottest spot temperature should not exceed 80^{O}C. It was hoped that the hottest spot rise could be inferred from measurements of oil temperatures, and average winding rise by measurement of resistance during standard commercial test in accordance with IEEE C57.12.90 (i.e. "heat run"). However, test results reported by IEEE and IEC indicates that the temperature calculated using simulated measurement methods deviate significantly from the actual "hot spot" temperature unlike the direct measurement using fiber optic probes.

Conclusion:

Heat run testing of hottest spot temperature rise is reliable only when employing direct real time winding temperature measurement using fiber optics.

Integration During Heat Run Tests:

- Install only the fiber optic probes (plant instrument can be used)
- Calibrate WTIs using fiber optic probe data

Assurance of Safe Transformer Loading During Operation

Simulated winding "hotspot" temperatures suffer from slow response times (3 - 5 hours) and gross errors at higher temperatures (see chart). As a result, excessively high winding temperatures can occur without the knowledge of the operations staff, particularly during transient loading. Winding Temperatures in excess of 200°C have been reported.

Conclusion:

Fiber optic hotspot measurement provides direct, accurate and real time winding temperature data to instantly provide temperature indications. These temperature measurements can be used to activate transformer cooling to prevent insulation damage from excessively high temperatures. In severe situations, a trip can also be invoked.

This capability enables the operations staff to safely bring the transformer through the overload status during transient loading, thereby providing a dynamic and reliable asset management tool.

Integration for Direct, Real Time Monitoring & Control

- Install fiber optic probes and instrument (WTS-22 Controller, ThermAsset® Monitor, ThermAsset®2 Monitor or m600 OEM Utility Module)
- Instantly activate transformer back up cooling systems using fiber optic probe data to protect the transformer from insulation damage during transient overloads
- Monitor hotspot temperature data to safely maximize normal loading without fear of damaging insulation or reducing transformer life

Financial Payback from Maximum Safe Loading

Financial payback from an investment in fiber optic Winding Hot Spot Temperature System (WTS) is derived from many factors:

- **Increased transformer loading** which equates to postponing added capacity
- **Longer transformer life** resulting from minimizing insulation breakdown
- **Preventing catastrophic failure** from overheating, particularly due to overloading conditions
- **Transformer design evaluation** by having accurate and timely knowledge of winding temperature during heat run testing

Conservative estimates by utility operations staff indicate that on an average, 10% additional loading capacity can be achieved by knowing true winding temperature. The cost of adding capacity is between $3K and $5K per MVA.

Given the cost of rebuilding or replacing transformers, it is easy to see that any means of minimizing the degradation of insulation, thereby extending transformer life, can be an extremely profitable investment in the long run. Assuming a transformer purchase cost of $2 million, an interest rate of 6% and expected lifetime of 25 years; the annual savings of extended lifetime is $200K.

Conclusion:
An investment in fiber optic hot spot monitoring in future transformer purchases can be easily justified by the benefits of safe increased loading and extending the life of the transformer.

Contact LumaSense to request the **"WTS Payback Analysis"** calculation program for your transformer by sending an email to info@lumasenseinc.com or call (408)727-1600.

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